An *in vitro* comparison of pH changes in root dentine following canal dressing with calcium hydroxide points and a conventional calcium hydroxide paste

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Abstract

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Aim This study aimed to measure and compare pH changes at apical and cervical sites on the external root surface of extracted teeth dressed with calcium hydroxide in two different formulations.

Methodology Root canals of 45 single-rooted extracted human teeth were accessed and shaped using a step-down technique with rotary instrumentation. Standard cavities were prepared on the external root surface at specific apical and cervical sites. The teeth were randomly allocated to three groups. Teeth in group A were dressed with calcium hydroxide points, those in group B were dressed with an aqueous calcium hydroxide paste and teeth in group C were left unfilled. Following storage in humid conditions, the pH of the dentine at apical and cervical sites was measured at baseline and then at 24 h, 72 h, 1 week, 10 days, 2 weeks and 3 weeks.

Results The pH of the root dentine at both apical and cervical sites was significantly greater ($P < 0.001$) in teeth dressed with aqueous calcium hydroxide paste compared with those dressed with calcium hydroxide points, when averaged out across all time periods. For all groups, there was a significant difference between the mean apical and cervical pH values for each tooth with lower values for the apical sites ($P < 0.001$).

Conclusion The results of this study indicate that an aqueous calcium hydroxide paste was more effective than calcium hydroxide points at raising the pH on the external root surface of extracted teeth.

Keywords: calcium hydroxide, dentine, endodontics, medicament, pH.

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Introduction

Calcium hydroxide is regarded as the material of choice for induction of hard tissue deposition and for the promotion of healing of vital pulpal and periapical tissues (Garcia 1983). In cases of trauma, the use of calcium hydroxide appears to be successful in arresting inflammatory root resorption, although the mechanism of action is not fully understood (Cvek 1973). However, it is appreciated that there appears to be a relationship between pulpal necrosis and inflammatory root resorption in traumatized teeth (Andreasen & Hjorting-Hansen 1966) which may be arrested by endodontic therapy (Andreasen 1971). One explanation is that diffusion of hydroxyl ions may occur through the dentinal tubules into conditions of resorption favoured by a low pH. Consequently, any rise in pH would be unfavourable for osteoclastic acid hydrolase activity (DeDuve & Wattiaux 1966). A number of investigators have examined the dynamics of diffusion of hydroxyl- ions through dentine in teeth dressed with calcium hydroxide. A study by Tronstad *et al.* (1981), for example, demonstrated that there

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was a pH gradient in the roots of monkey teeth 1 month after placement of a calcium hydroxide dressing, with higher values around the canal compared with more peripheral sites. Nerwich *et al.* (1993) used microelectrodes to look at the diffusion through root dentine with time and demonstrated that hydroxyl ions do diffuse through to the intact root surface, albeit in a minor way.

Calcium hydroxide itself is a white odourless powder with a molecular weight of 74.08. It has a low solubility in water and a high pH (12.5–12.8). When the powder is mixed with a suitable vehicle, a paste is formed. Leonardo *et al.* (1982) recommended the addition of substances other than water to the paste to maximize its consistency, flow, pH, clinical handling and radio-opacity. In the past, three types of vehicle have been used: aqueous, viscous or oily (Fava 1991, Holland 1994), selection of the appropriate vehicle depending on the clinical situation. If rapid ionic liberation at the commencement of treatment is required, an aqueous vehicle is indicated, whilst a viscous vehicle is appropriate when a more gradual and uniform release is necessary. Oily vehicle pastes have limited application.

Calcium hydroxide points (Calciumhydroxid, Roeko, Langenau, Germany) are a relatively recent development and are designed to release calcium hydroxide from a gutta-percha matrix. The constituents of the points include 58% calcium hydroxide, 42% gutta-percha and colouring agents. The points are 28 mm in length, are light brown in colour and have similar handling characteristics to conventional gutta-percha points. They are available in ISO sizes 15–140. The manufacturers indicate that their use includes intracanal dressing between appointments and treatment of root resorption. When used as an intracanal dressing, they recommend that a point should be inserted into the canal to the working length and should sit passively such that moist air is able to circulate freely. It is suggested that a point one size smaller than the master apical file should be placed and that the canal should then be sealed with a cotton wool pledget and a temporary restorative material. It is recommended that the point should be left for up to 3 weeks. The points are claimed to leave no residual material and can be removed easily with tweezers or a Hedstrom file.

In a study by Larsen & Hörsted-Bindslev (2000) the hydroxyl-releasing potential of such points was reported to be less than that of a slurry of pure calcium hydroxide and water or a commercial paste after 2 h in a variety of buffering solutions within a narrow test tube. They also reported that the slurries contained more than 10 times as much calcium hydroxide per specimen than did the gutta-percha points. With respect to their antibacterial properties, Podbielski *et al.* (2000) found that calcium hydroxide impregnated gutta-percha points were more effective than points containing either zinc oxide, a mixture of zinc oxide and chlorhexidine, iodine-polyvinylpyrrolidone or a mixture of chlorhexidine, iodine-polyvinylpyrrolidone and zinc oxide.

A variety of experimental approaches have been used to measure diffusion of hydroxyl ions through dentine, including the use of pH indicating papers or solutions (Tronstad *et al.* 1981), pH measurement of ground dentine (Wang & Hume 1988) and pH measurement of the surrounding medium (Fuss *et al.* 1989). Though pH papers and indicators can be used as a guide, they may be limited in accuracy and can be difficult to interpret correctly. The use of a high impedance pH meter, together with a pH measuring electrode and reference electrode was found to be accurate by Larsen & Hörsted-Bindslev (2000) and gives a numerical record.

The aim of this study was to evaluate the pH changes at different sites in the root dentine of extracted teeth over 3 weeks following dressing with Calciumhydroxid points (Roeko) and a calcium hydroxide paste (Hypocal, Ellman International Inc, NY, USA), compared with an unfilled group.

Methodology

Canal preparation

Forty-five freshly extracted single-rooted permanent teeth were stored at room temperature in a buffered formal saline solution of pH 6.8. The teeth were measured with a protractor, any roots bearing more than 10° of curvature were excluded from the study. A radiograph of each tooth was viewed under magnification to verify the existence of a patent canal from the coronal aspect to the apical end. Access cavities were created using a 565 diamond bur in an air turbine hand-piece. Following removal of the pulp chamber roof using a 010 round bur (Dentsply Maillefer SA, Ballaigues, Switzerland) initial enlargement of the canals was carried out using size 2, 3 and 4 Gates Glidden burs and the root canal system was irrigated with sodium hypochlorite (1.5%). Canal orifice shaping was carried out using ProFile Orifice Shapers (Dentsply Maillefer SA) rotating at a constant speed of 200 r.p.m. in a 20 : 1 speed reducing hand-piece connected to a variable speed-constant torque electric motor, the files being coated in a canal lubricant (File-eze, Ultradent Products Inc, UT, USA). The working length

was determined by conventional radiographic techniques. Canal shaping continued with 0.06 Profile instruments to size 30, 1 mm short of the radiographic apex with the irrigating solution being introduced into the canal after every file using a 5-mL Luer-Lok syringe (Monoject, Mansfield, MA, USA) via a 25-mm, 28-gauge irrigating Endoneedle (VMK, Vedefar, Belgium). No more than 10 mL of irrigating solution was used for each tooth throughout the whole cleaning and shaping process.

Following the cleaning and shaping procedure, each canal was finally flushed with 10 mL of deionized water via a 25-mm, 28-gauge Endoneedle.

Cavity preparation

Using a round 014 tungsten carbide bur rotating at 1500 r.p.m. in a speed reducing hand-piece, two cavities were created on the thickest external aspect of the root surface as determined by the preoperative radiograph to the maximum depth of the bur head. One cavity was located 3 mm from the apical foramen, the other 3 mm from the enamel–dentine junction. All teeth were stored in deionized water for 3 days, over which period of time the water was changed five times. The pH in each root cavity was then measured (*vide infra*).

Placement of dressing materials

The 45 teeth were randomly allocated into three groups of 15. Those in group A were dressed with a calcium hydroxide point, those in group B with a calcium hydroxide paste and those in group C were left empty.

Group A

Each canal was dried with paper points. A size 25 calcium hydroxide point (Calciumhydroxid) was selected such that it reached the full working length. The coronal end was cut to size with scissors, and the access cavity sealed with Cavit (ESPE, Seefeld, Germany) over a dry cotton wool pledget placed over the canal entrance.

Group B

Each canal was dried with paper points. The proprietary calcium hydroxide paste (Hypocal, Ellman International Inc, Hewlett, NY, USA) was introduced directly via the syringe needle provided by the manufacturers. The needle was placed into the canal until resistance was encountered, then withdrawn by 1 mm. The plunger was rotated such that the calcium hydroxide paste was delivered into the canal and then withdrawn slowly. A lentulo-spiral filler was introduced into the canal such that it was within 2 mm of the apical preparation and rotated at 1500 r.p.m. for 10 s. Once the calcium hydroxide material was seen to occupy the canal at the orifice level, the paste was compacted vertically with a sterile cotton wool pledget and the procedure repeated until the material was seen to occupy the canal up to the level of the canal orifice. The access cavities were sealed with Cavit.

Group C

The access cavities of the control teeth were dried with paper points and sealed with Cavit.

All teeth were stored individually in numbered glass vials containing 2.5 mL of deionized water at a constant 37°C. The pH was measured at baseline, after 24 h, 72 h, 1 week, 10 days, 2 weeks and 3 weeks following placement of the dressings.

Determination of pH

Calibration of the pH meter and probe was first carried out using two buffering solutions of pH 7 and 9.33. Each tooth was then individually mounted in a block of Blu-Tack (Bostik Ltd, Leicester, UK) on a bench surface with the root cavities facing upward. The cavities were gently blotted dry with tissue paper. Using a variable volume micropipette (Acura, Wheaton Science Products, Millville, NJ, USA), 2 μL of deionized water were placed into the cervical cavity and allowed to stand for 15 s.

The calibrated microelectrode (Model MI4152 Microelectrodes Inc., NH, USA) was gently placed into the cavity and held in a vertical position for approximately 45 s until the pH reading stabilized. The reading was noted and then 2 μL of deionized water was placed into the apical cavity and allowed to stand for 15 s, whilst the microelectrode was rinsed in deionized water. The microelectrode was inserted into the cavity for approximately 45 s until the pH reading stabilized and the reading was then noted. The microelectrode was rinsed with deionized water between teeth. Recalibration was carried out every 15 min.

When not in use, the microelectrode was kept in a buffering solution of pH 4.

Determination of dentine thickness

Each root was sectioned using a diamond wheel saw (South Bay Technology Inc., San Clemente, CA, USA) in

Table 1 Mean and standard deviation of apical pH values at different times

Group		0 days	24 h	72 h	1 week	10 days	2 weeks	3 weeks	Mean
A (Points)	Mean (n = 15)	7.64	9.23	9.67	9.99	10.07	9.95	10.38	9.88
	SD	0.12	0.18	0.16	0.17	0.11	0.07	0.13	0.04
B (Paste)	Mean (n = 15)	7.61	9.83	10.98	11.21	11.12	10.89	11.24	10.88
	SD	0.16	0.12	0.13	0.12	0.26	0.07	0.11	0.06
C (Control)	Mean (n = 15)	7.62	7.25	6.93	6.68	6.95	6.88	6.83	6.92
	SD	0.18	0.10	0.12	0.18	0.07	0.04	0.10	0.05

Table 2 Mean and standard deviation of cervical pH values at different times

Group		0 days	24 h	72 h	1 week	10 days	2 weeks	3 weeks	Mean
A (Points)	Mean (n = 15)	7.67	8.75	9.69	10.49	10.52	10.63	10.55	10.10
	SD	0.16	0.13	0.14	0.11	0.14	0.09	0.05	0.05
B (Paste)	Mean (n = 15)	7.64	10.64	11.40	11.27	11.09	11.57	11.23	11.23
	SD	0.20	0.09	0.13	0.13	0.18	0.12	0.15	0.07
C (Control)	Mean (n = 15)	7.61	7.23	6.93	6.71	6.96	6.49	6.58	6.82
	SD	0.15	0.08	0.10	0.10	0.11	0.11	0.06	0.03

a perpendicular direction to the long axis of the tooth 0.5 mm coronal to the centre of the cervical cavity to reveal a cross-section of the centre of the cavity. The coronal part of the tooth was discarded. The calcium hydroxide point was removed from the teeth in group A. For those teeth in group B, the canal was flushed with 10 mL of deionized water from a hypodermic syringe. All roots were then irrigated with 10 mL deionized water. The thickness of dentine between the floor of the cervical cavity and the canal was measured using electronic callipers.

Each root was then sectioned with a diamond wheel at 90° to the long axis through the centre of the apical cavity. The apical portion of the root was discarded. The thickness of the dentine was again recorded.

Statistical analysis

The mean apical and cervical thickness values, and baseline pH values for the three groups were compared by the one way analysis of variance F-ratio test. The mean apical and cervical pH value for each tooth was calculated from the 1–21 days values and the mean values for the three groups were compared by the one way analysis of variance F-ratio test, followed by the post hoc pairwise comparison using the Bonferonni modification to the P-value. A comparison between the mean apical and cervical pH values was made for teeth in all groups, using a paired t-test. An overall significance of 0.05 was used for each analysis.

Results

Dentine thickness

The mean thickness between the floor of the apical cavity and the root canal was 0.90 mm (SD 0.07) and the mean thickness in the cervical cavity was 1.51 mm (SD 0.15). There was no significant difference in dentine thickness between the experimental groups either apically ($P = 0.617$) or cervically ($P = 0.812$).

pH values

Tables 1 and 2 show the mean pH values in the apical and cervical sites for the three groups. There were no significant differences in the baseline pH either apically ($P = 0.84$) or cervically ($P = 0.62$).

In group A, the highest mean pH value was 10.38 at the apical site after 3 weeks and 10.63 at the cervical site after 2 weeks. In group B, the highest mean pH value was 11.24 at the apical site after 3 weeks and 11.57 cervically after 2 weeks. In group C, the highest mean pH values were at baseline for both cervical (pH 7.61) and apical (pH 7.62) sites. The lowest mean pH in this group was 6.68 apically after 1 week and 6.49 at the cervical site after 2 weeks.

There was a significant difference in pH between all pairs of groups at the apical site ($P < 0.001$) (Table 1) with the mean values for group B being greater than those for group A which, in turn, were greater than those for group C.

There was a significant difference between the mean pH values at the apical and cervical sites, for each tooth, with lower pH values for the apical sites ($P < 0.001$).

A sudden rise in pH was recorded within the first 3 days in group B at the cervical site, reaching approximately pH 11.4 and then levelling to over pH 11 for the remainder of the time (Table 2). Group A also demonstrated a rise in pH but to a level of pH 10.5 and this took 1 week to achieve. Group C dropped to pH 6.7 over the first week.

There was a significant difference between all pairs of groups at the cervical site ($P < 0.001$) (Table 2) and this reflected the differences recorded for the apical mean pH values (Table 1) with the mean pH values for group B being greater than those for group A which were, in turn, greater than those for the control group.

Discussion

This study was intended to investigate the diffusion dynamics of hydroxyl ions through root dentine with time by measuring the rapidity, magnitude and duration of pH change on the external aspect of the root at apical and cervical levels in roots dressed with calcium hydroxide points and paste. It was found that the pH increased after dressing with both preparations, concurring with the findings of Tronstad *et al.* (1981), who examined histological sections of monkey teeth with experimentally induced root resorption, 1 month after placement of a calcium hydroxide root canal dressing. Using pH indicator solutions, they noted that there was a pH gradient with high values around the canal decreasing toward the dentine on the periphery. When cementum was present, the pH remained unchanged, but in areas of resorption in which the cementum was not present, the pH of the dentine root surface increased. This was attributed to the outward diffusion of hydroxyl ions via the dentinal tubules. Wang & Hume (1988) also measured hydroxyl ion diffusion across dentine between an occlusal cavity containing calcium hydroxide and a saline-filled pulp chamber, using a pH meter and noted that there was a pH gradient from the cavity floor decreasing toward the middle and pulpal layers.

In our study, the greatest change was recorded cervically, a strategic area of tooth also considered by Kehoe (1987), who investigated the action of calcium hydroxide in cases of cervical root resorption. Calcium hydroxide was placed in the cervical part of root canals previously filled with bleaching agents. Using pH electrodes and alkacid test papers, Kehoe recorded a reversal from a slightly acid environment to one which was slightly alkaline.

In teeth dressed with calcium hydroxide points, the initial pH rise was more rapid apically in the initial period. This may have been due to a closer approximation of the point to the canal wall. The overall pH rise at apical and cervical sites was significantly greater in the paste group compared with the point group. The finding that the pH was lower in both points and paste groups of teeth at the apical aspect may be attributed either to the size and orientation of the dentinal tubules or to the fact that there was closer contact of the material with the root dentine coronally. The use of a point one size smaller than that of the canal preparation size may have been influential in this respect. This finding may be of significance in teeth bearing narrow canals when use of a calcium hydroxide impregnated point could facilitate controlled placement at, and removal of the medicament from the desired site.

Certain aspects of our experimental model may have had a minor effect on the outcome. For example, a chelating agent was not used, because it was possible that use of such a material may have affected the pH dynamics. Radiographs were not taken to check placement of the calcium hydroxide paste material for teeth in group B, following a pilot study in which all canals were shaped to a uniform size which easily accommodated placement of the delivery needle. A further consideration is related to the experimental environment. Dissociation of calcium hydroxide is dependent on the constitution, quantity and buffering environment of the surrounding medium. In the *in vitro* situation, there could be large variations between these factors in different teeth. In our experimental model, a controlled environment was established in order that other variables could be meaningfully tested.

Conclusions

The results of this study indicate that the rise in pH of root dentine at apical and cervical sites was significantly greater ($P < 0.001$) in teeth dressed with a proprietary calcium hydroxide paste material compared with teeth dressed with calcium hydroxide points. For all groups, from 24 h, there was a significant difference in pH between apical and cervical sites with that at the apical being lower. Our findings confirm that placement of a calcium hydroxide material in either point or paste formulation as an interappointment dressing is effective at raising the pH at all external aspects of the root surface.

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